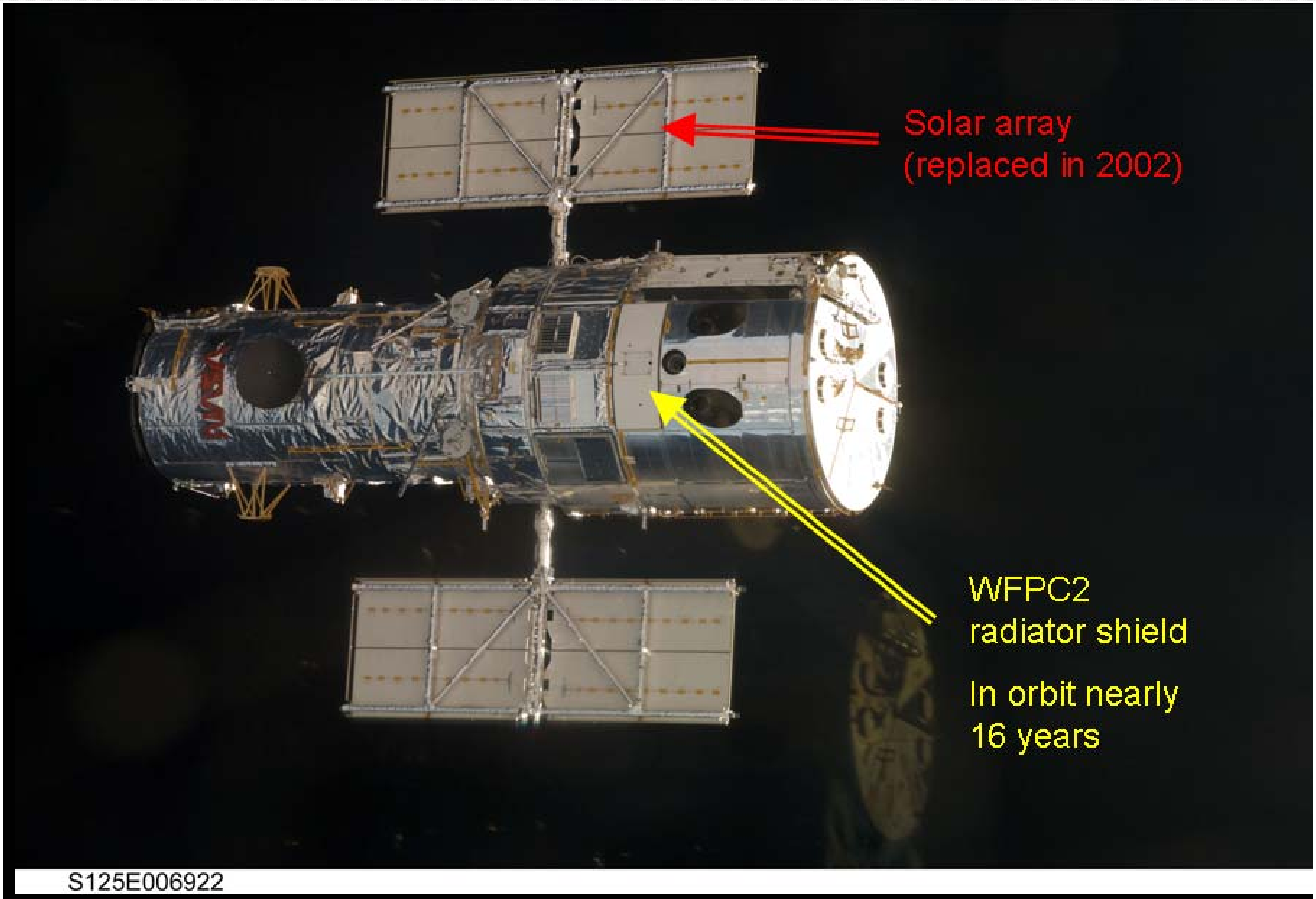
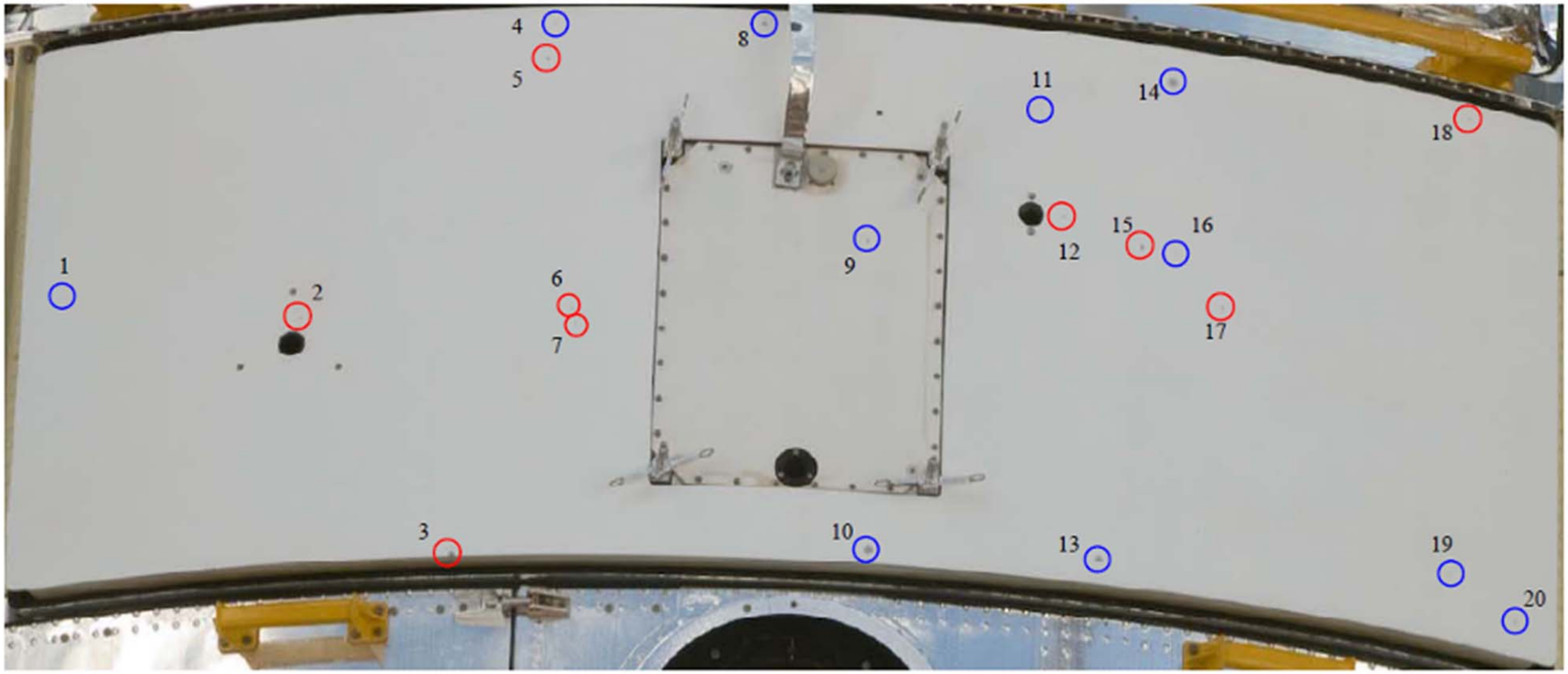
SAMPLING AND ANALYSIS OF IMPACT CRATER RESIDUES FOUND ON THE WIDE FIELD PLANETARY CAMERA-2 RADIATOR

P. D. Anz-Meador[1] , J.-C. Liou[2], D. Ross[1], G. A. Robinson[1], J. N. Opiela[1] A. T. Kearsley[3] , G. W. Grime[4], J. L. Colaux[4], C. Jeynes[4], V. V. Palitsin[4], R.P. Webb[4], T. J. Griffin[5], B. B. Reed[5] and L. Gerlach[6]

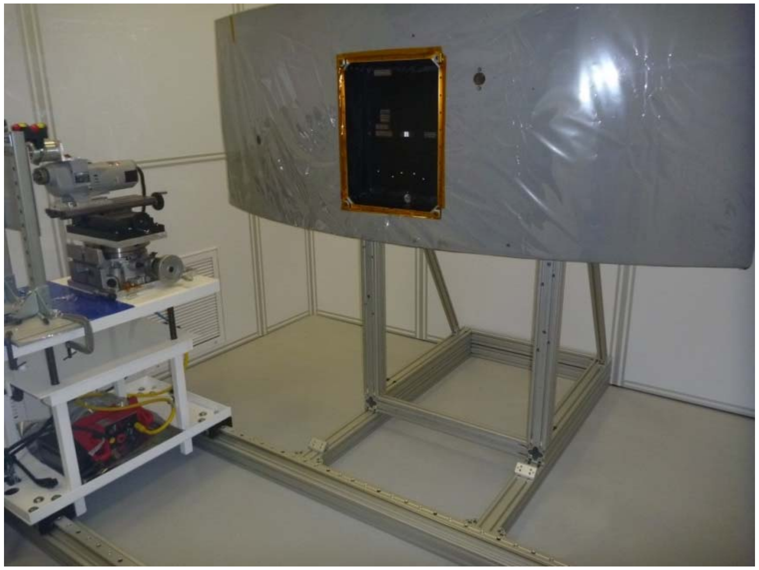
(1) ESCG Jacobs, Houston, Texas, USA. (2) NASA Johnson Space Center (JSC), Houston, Texas, USA. (3) Science Facilities, Natural History Museum (NHM), London, United Kingdom, Email: antk@nhm.ac.uk (4) Ion Beam Centre (IBC), University of Surrey, Guildford, United Kingdom (5) NASA Goddard Space Flight Center (GSFC), Greenbelt, Maryland, USA. (6) European Space Agency (ESA, retired), Noordwijk, The Netherlands.


Solar array
(replaced in 2002)
WFPC2
radiator shield
In orbit nearly
16 years
S125E006922



S125e006995.jpg (edited)

Large impact features on WFPC2, seen from the cargo bay window of STS-125orbiter *Atlantis*. Impacts from before service mission 3B (2002) are in red circles, new impacts from 2002 – 2009 are in blue circles. Almost 700 features ≥ 300 μm.

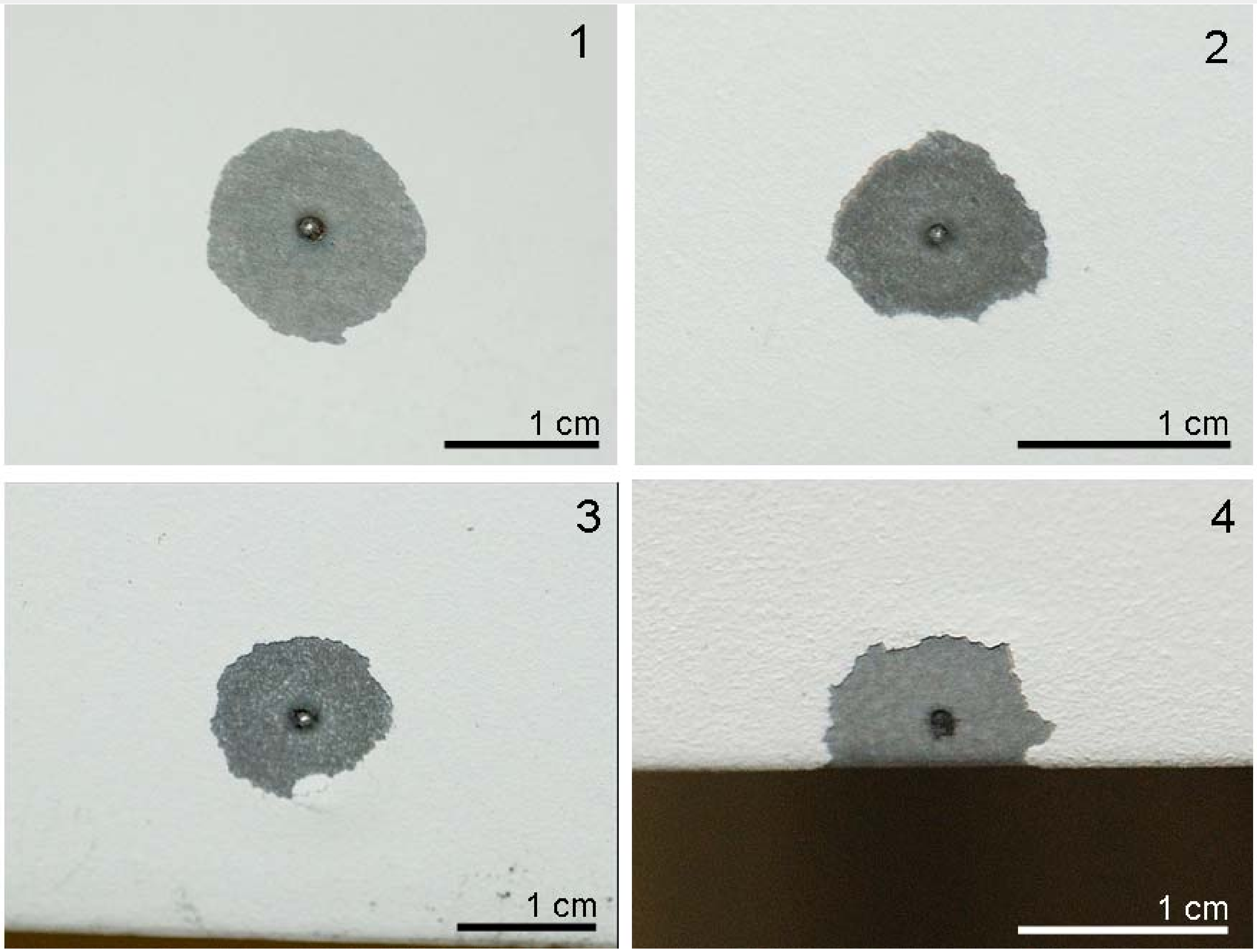


Post flight activities

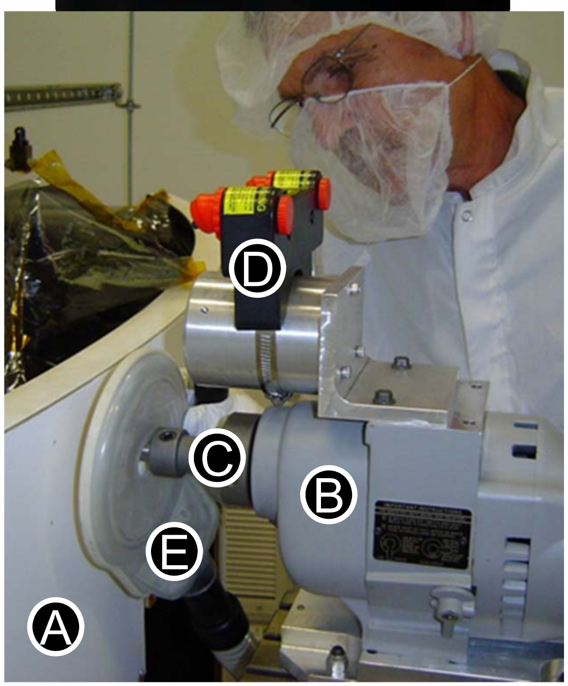
(top) after retrieval by STS-125, WFPC2 inserted into NASA Goddard class 100k clean room; joint NASA center's MMOD inspection conducted July-September 2009

WFPC 2 exhibited at Smithsonian, NASA JPL, Denver science museum Nov. '09-September '11

(bottom) the WFPC2 radiator received in Space Exposed Hardware (SEH) class 10k clean room at NASA JSC, December 2011; mounted on coring frame with (left) coring apparatus



Larger impacts on WFPC2 radiator shield in Space Exposed Hardware (SEH) class 10k clean room at NASA JSC



The NASA JSC coring apparatus

(top) a closeup of the standard 5/8” (~ 16 mm) annular cutter, modified with a spring-loaded phosphor-bronze coaxial cylinder; cylinder’s O ring protects feature during coring

(bottom) primary features of the coring apparatus in action

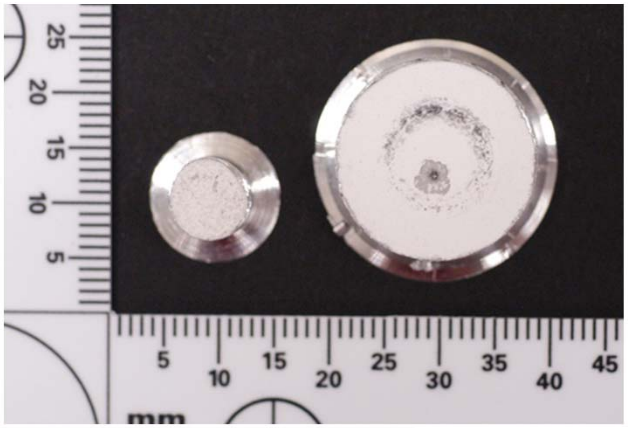
A – WFPC2 radiator surface

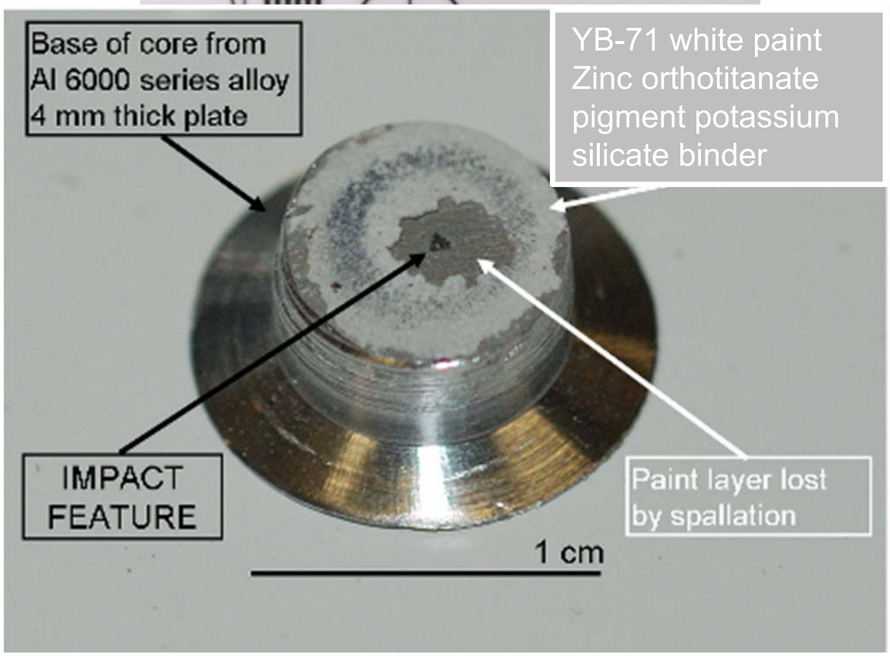
B - Drill motor

C - cutting tool engaged

D - laser “X” alignment system

E – vacuum shroud (collects dust, chips, Al strands to protect cleanroom environment)





The NASA JSC coring apparatus

(top) two exemplar cores; small core is a "blank" reference taken as a standard, large core displays crater & paint spallation

(bottom) primary features of a core

Circular abrasion feature created by cutter's O ring

National Aeronautics and Space Administration

How do we infer the origin of an impacting particle? Look for extraneous elemental signatures:-

MICROMETEOROID

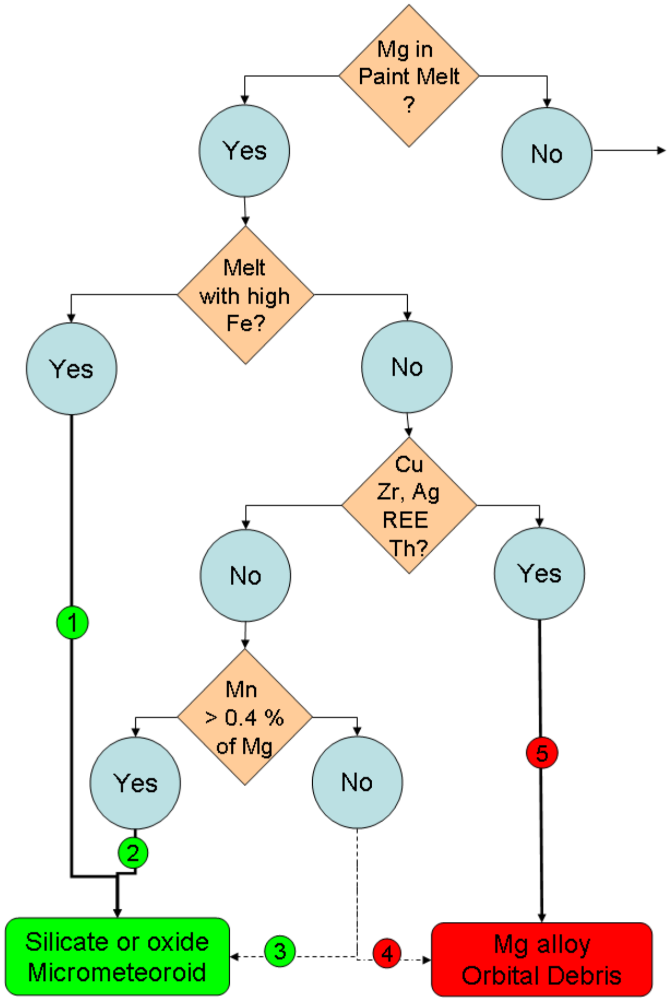
Mg Si O	Forsterite/Enstatite
Mg Fe Si	Olivine/o-pyroxene
Mg Fe Ca Si O	Clino-pyroxenes
Na Ca Al Si O	Feldspar
Na Al P K Ca Ti Si O	Mesostasis glass
Mg Al O	Spinel sensu strictu
Mg Al Cr Fe O	Spinel sensu lato
Fe S	Troilite
Fe Ni S	Pentlandite
Fe Cr S	Daubreelite
Fe Ni P	Schreibersite
Fe Ni	Kamacite/Taenite
Mg Si S Fe Ni	‘chondritic’

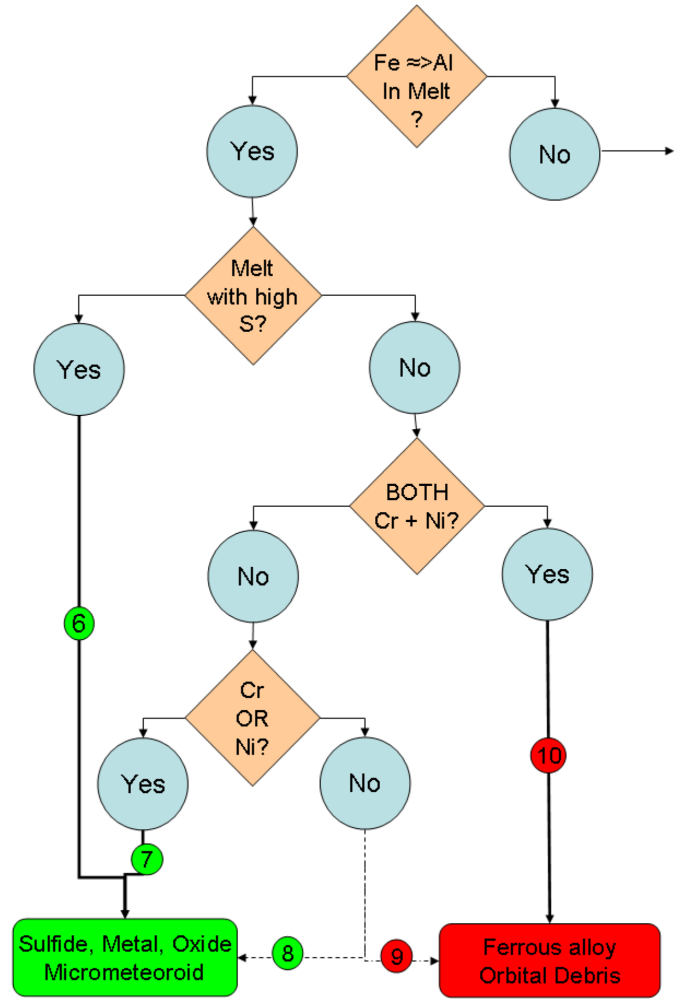
ORBITAL DEBRIS

Mg Al Mn Zr	Mg alloy
Al Mg Cr Mn Fe Cu Zn	Al alloy
Al O	SRM debris
B Na Si K Ce O	Cover glass
Si Na Ca O	Glass fibre
Fe Cr Ni	Stainless steel
Ag	Silver connector
Cu Zn Pb	Non-ferrous alloy
Sn In	Solder
Na K	Coolant droplet
C F	Fluoropolymer
C N O	Polymers
Na P S Cl K	Body fluid

Can we be objective…. or at least consistent in approach?

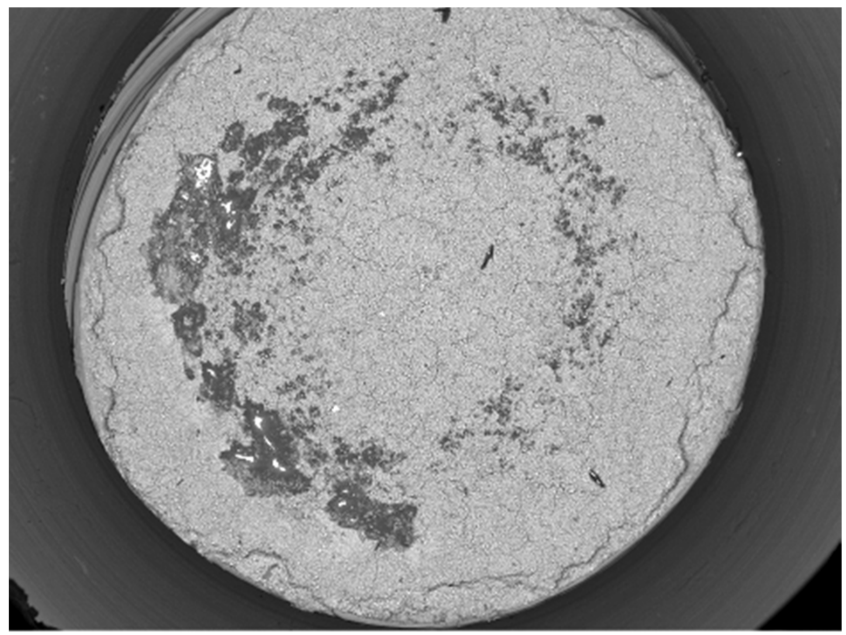
Decision Trees

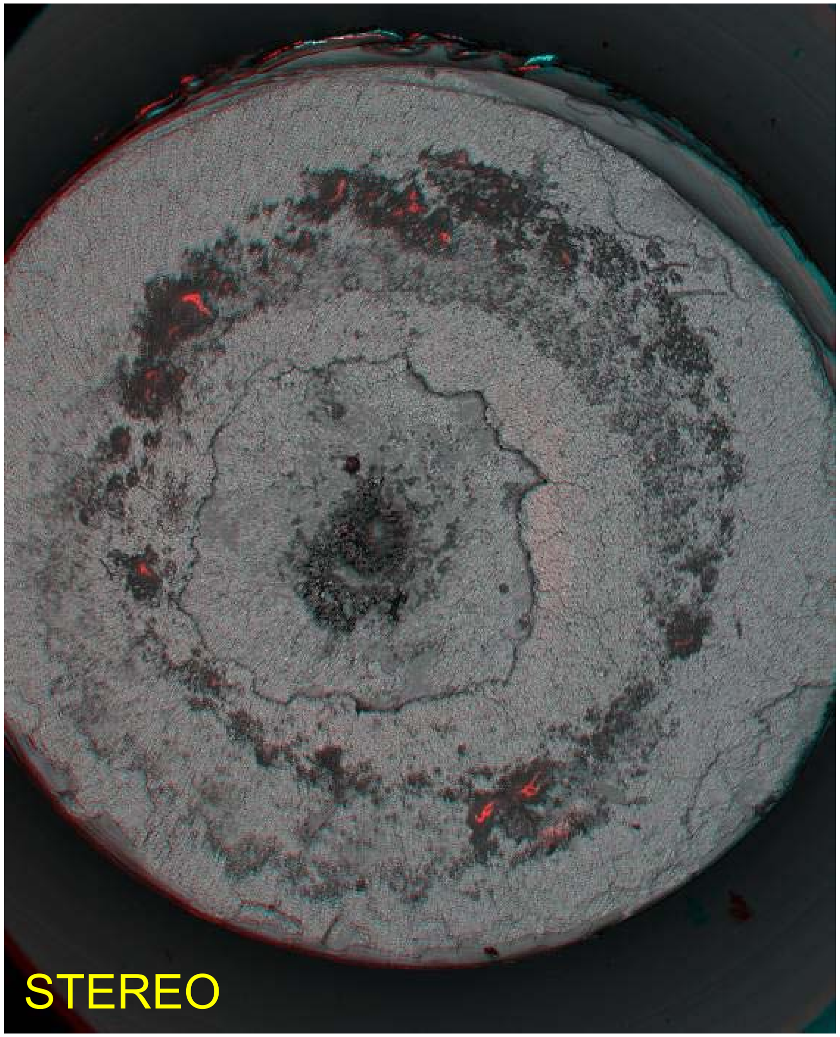




Secondary Electron Imagery (SEI)

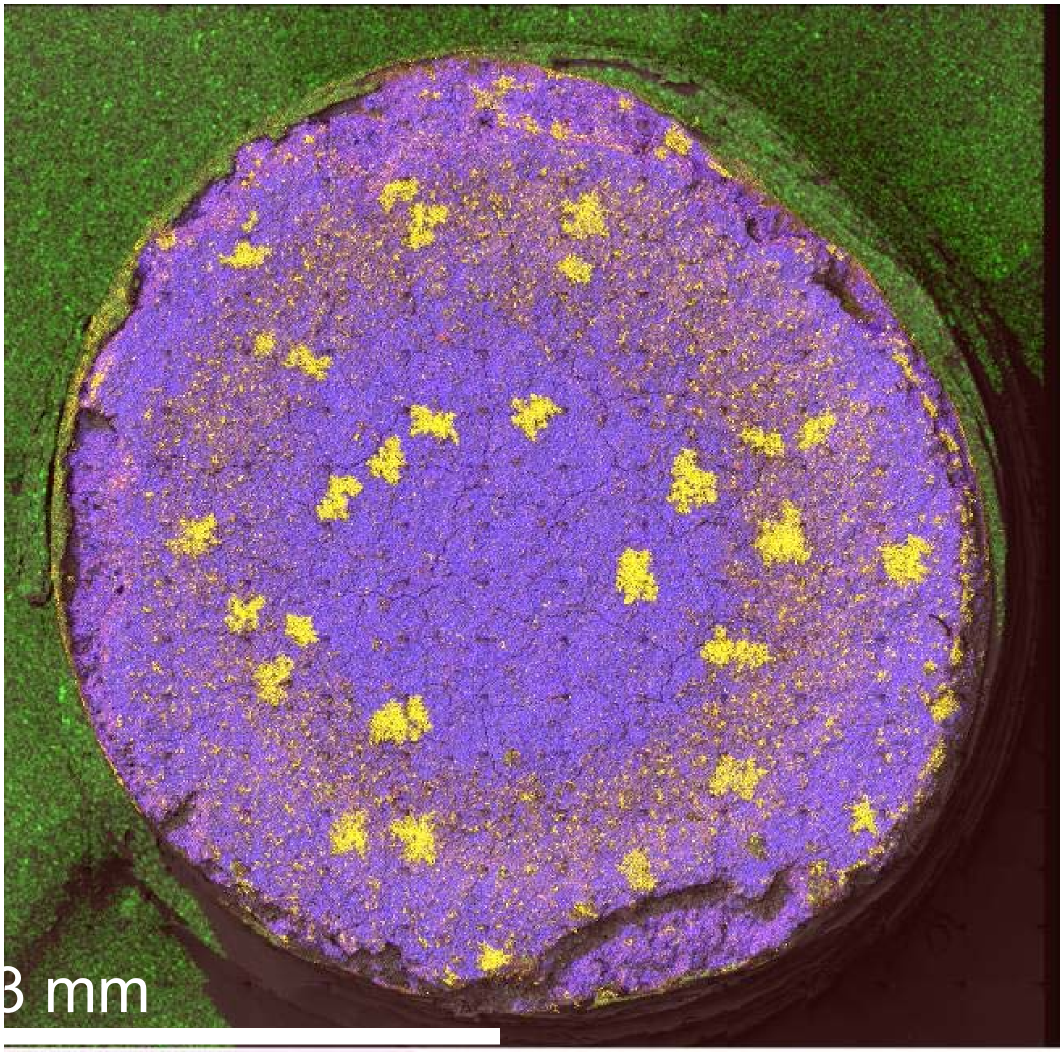
Backscattered Electron Imagery (BEI)



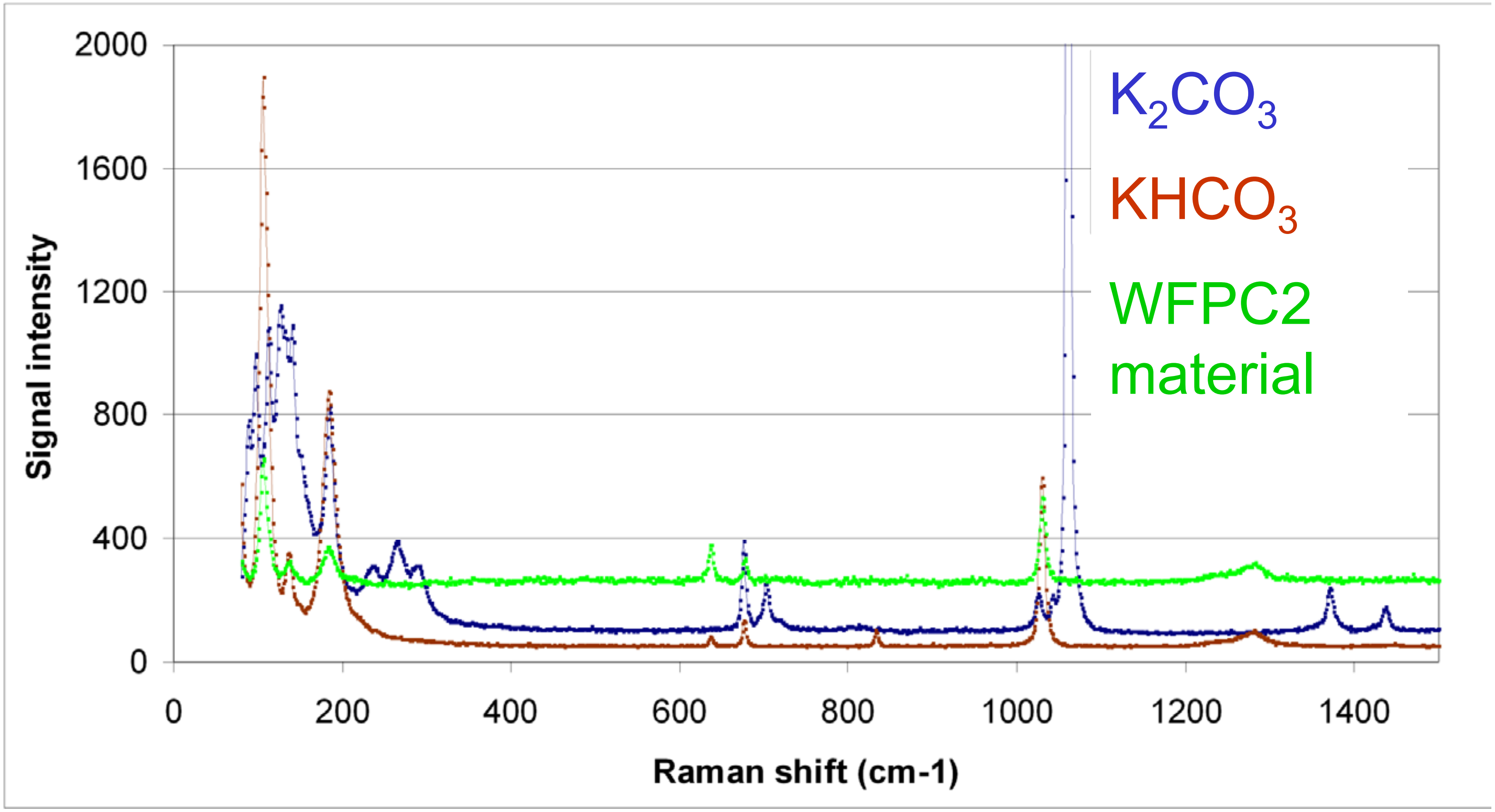


'O' ring debris may be unsightly but is not a real problem for imaging/analysis

$KHCO_3$ is a slight, but more 'soluble', problem.



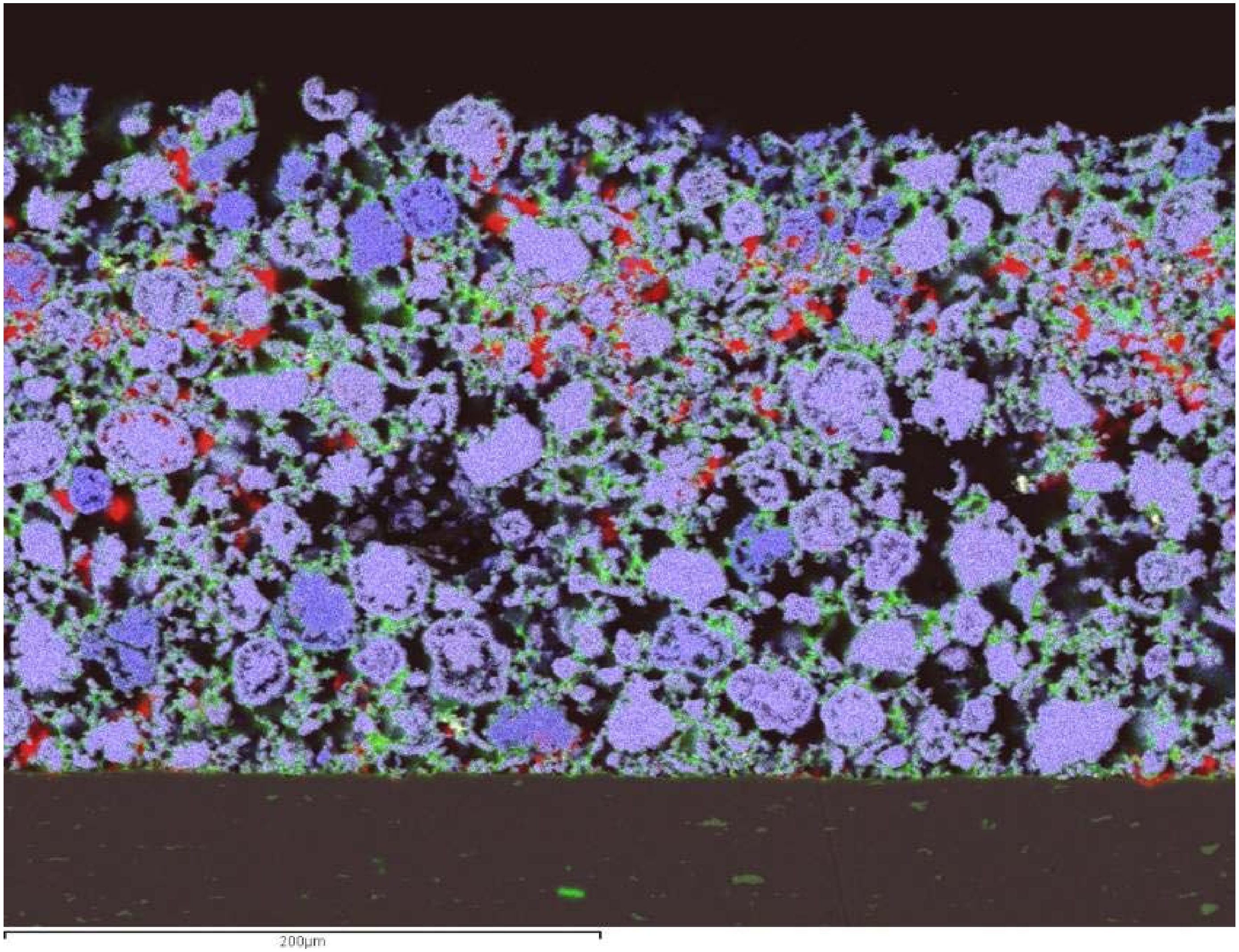
Mg
Si
K
TiZn
BEI

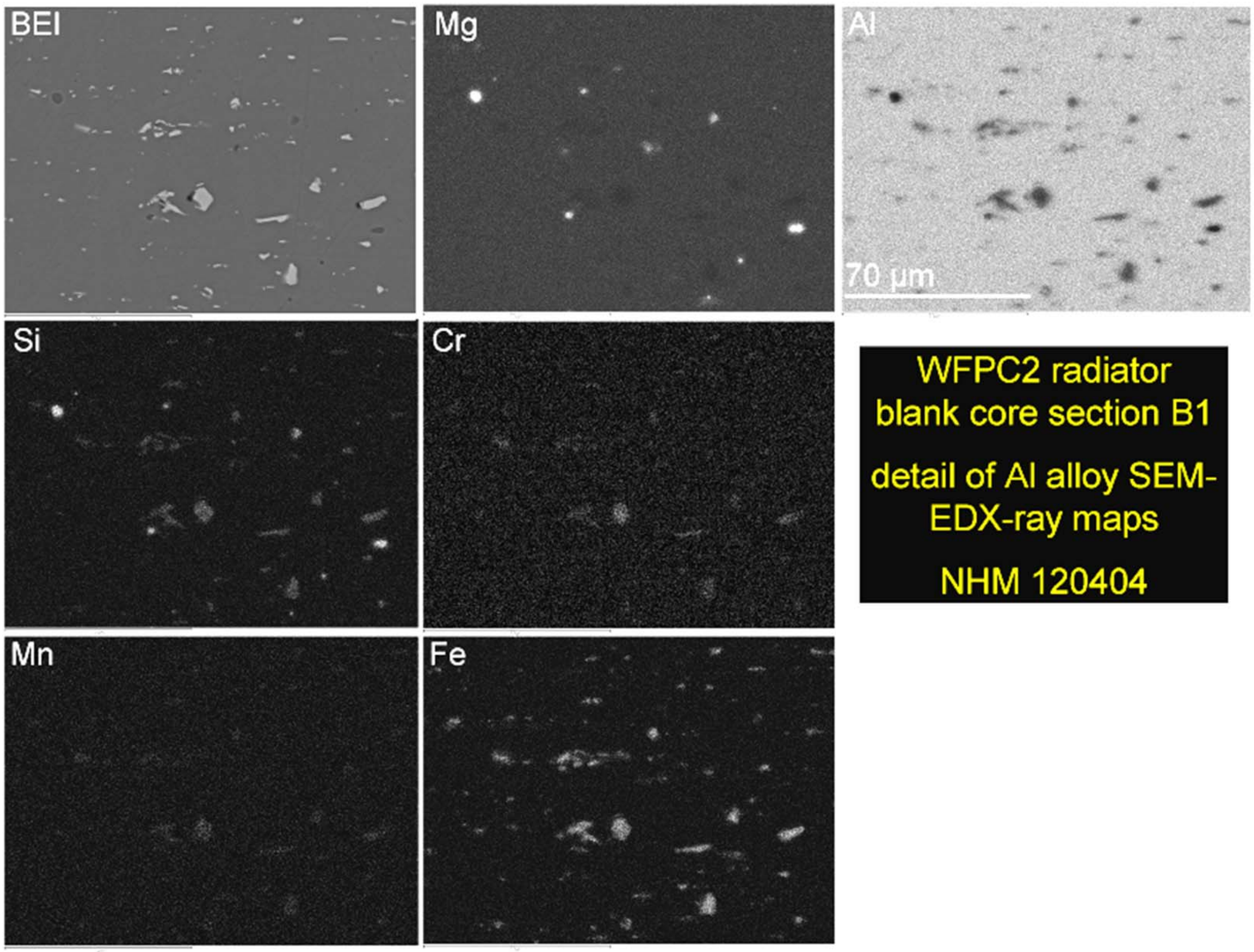


Potassium can move almost everywhere on the paint layer, into impacts.

Raman revealed a soluble, hygroscopic, reactive material - $KHCO_3$

BEI K Si Ti Zn



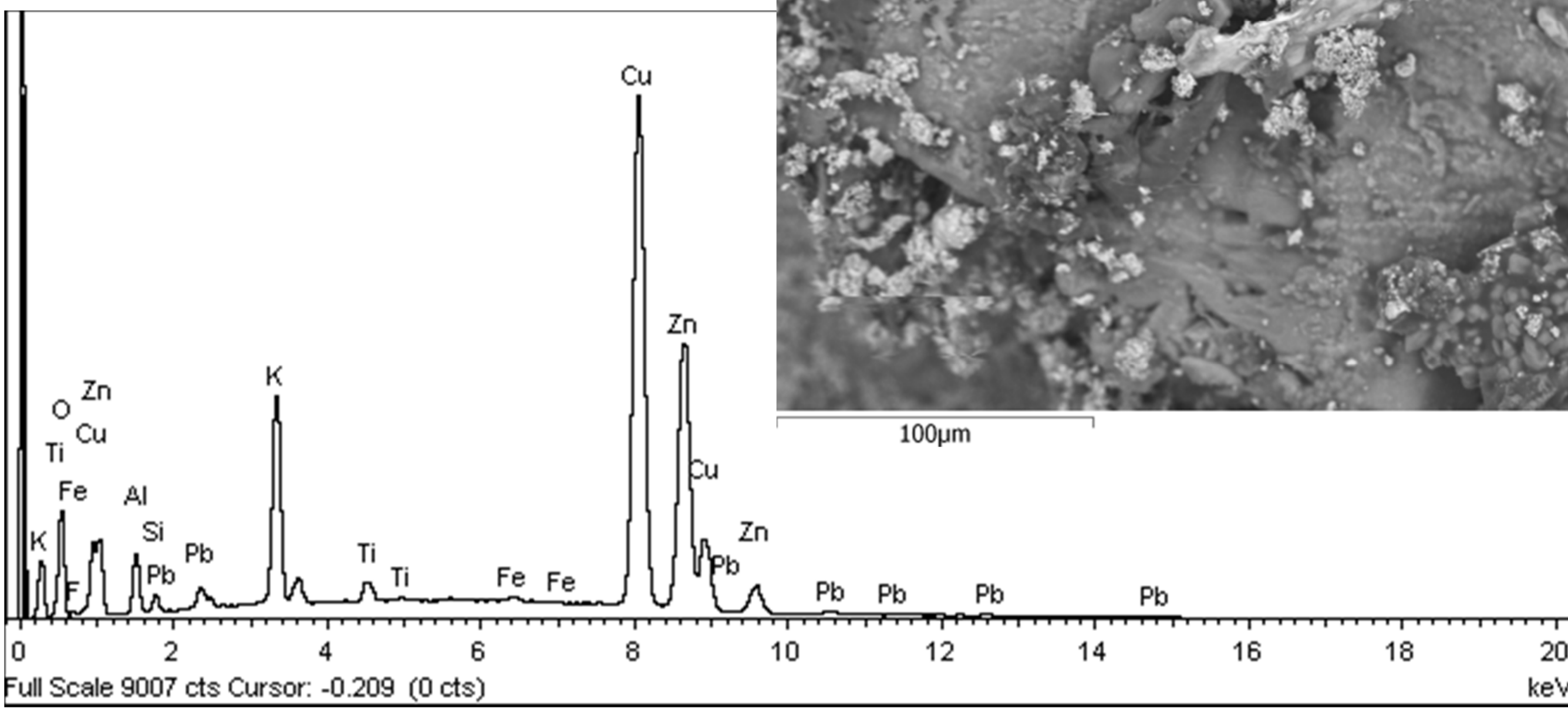


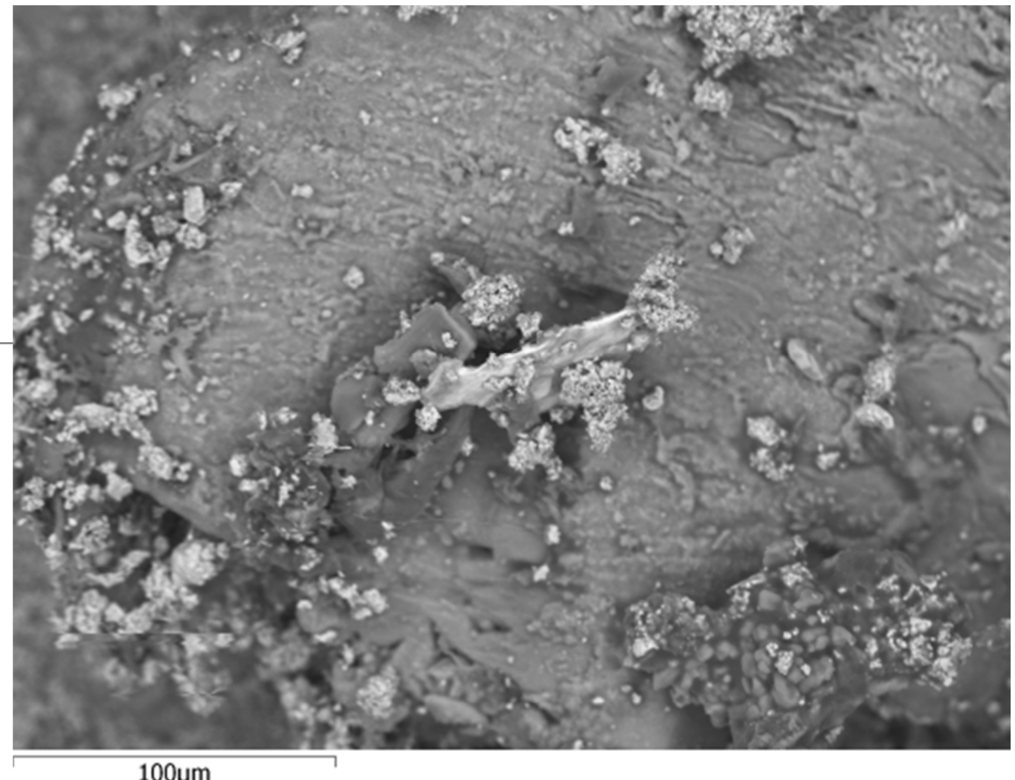
WFPC2 radiator blank core section B1

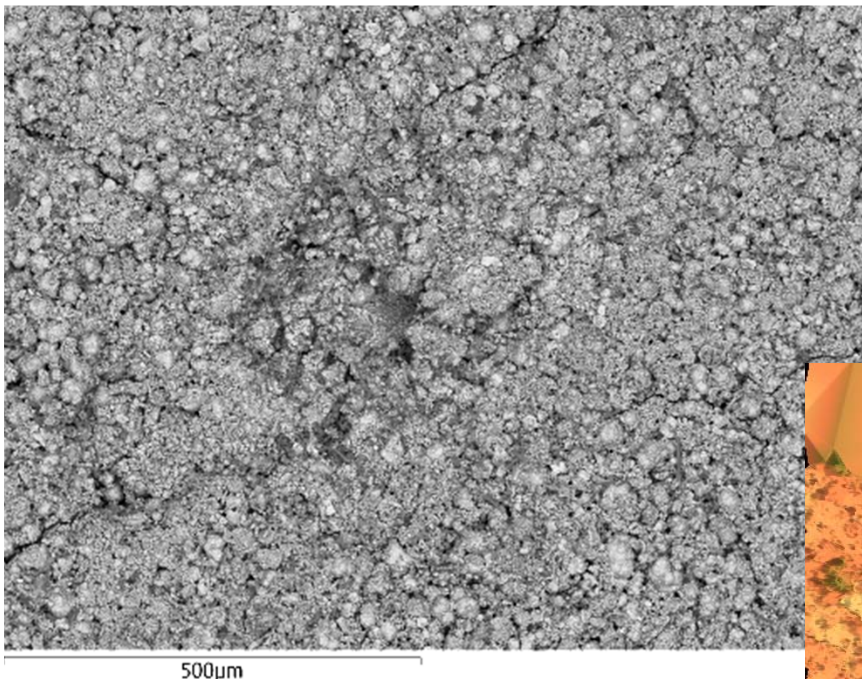
detail of Al alloy SEM-EDX-ray maps

NHM 120404

Loose particles need to be treated with care – not an impact remnant

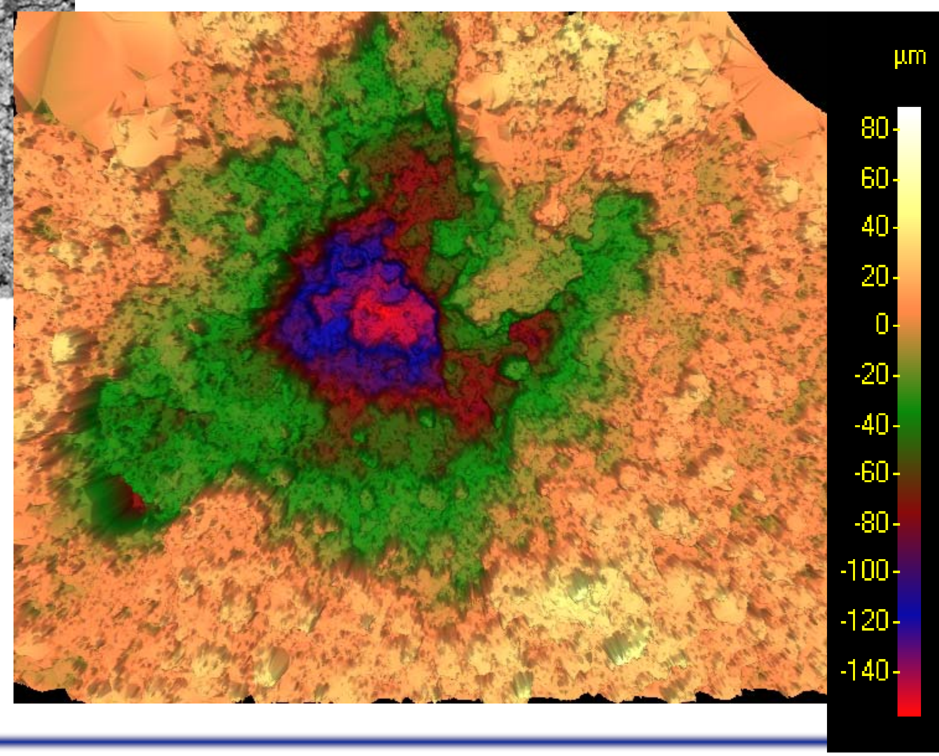




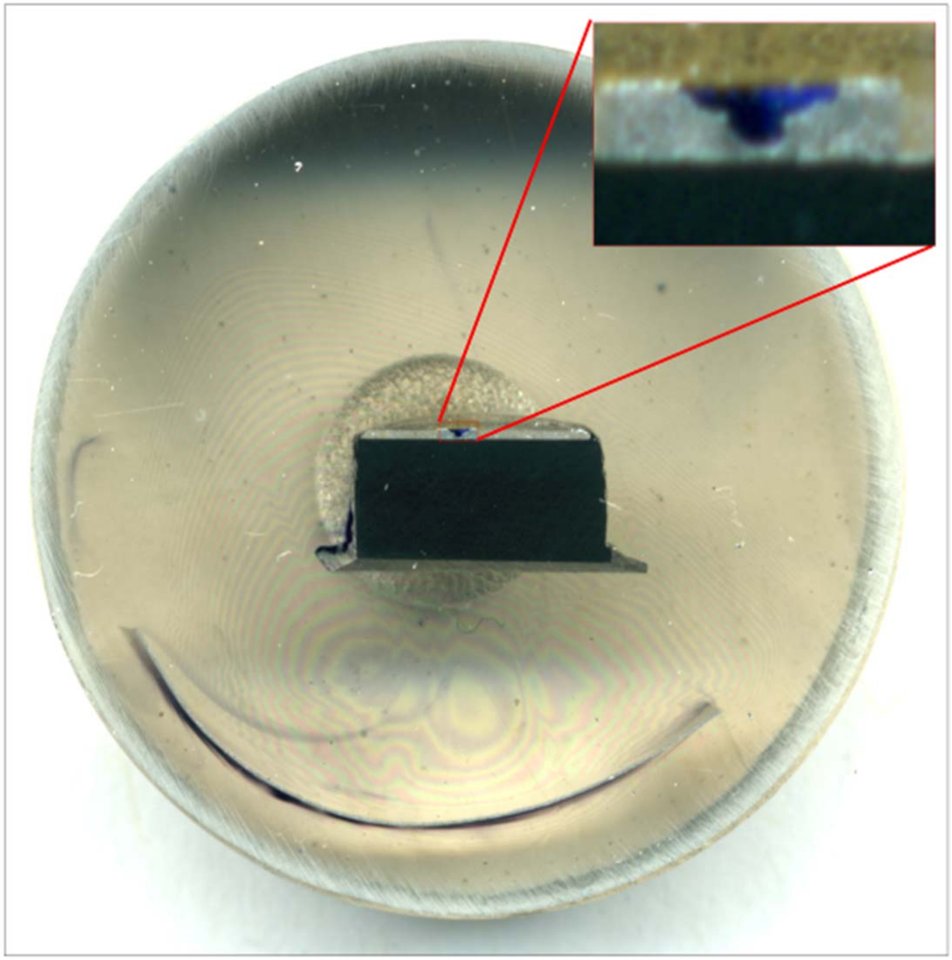


Craters are difficult to recognise and measure

WFPC2-sample 109

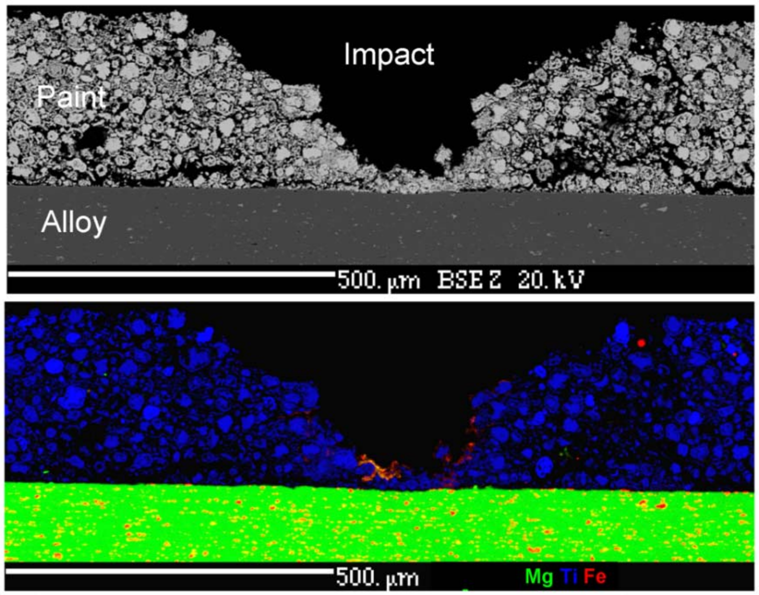


Digital elevation model reveals shape, and gives measurements

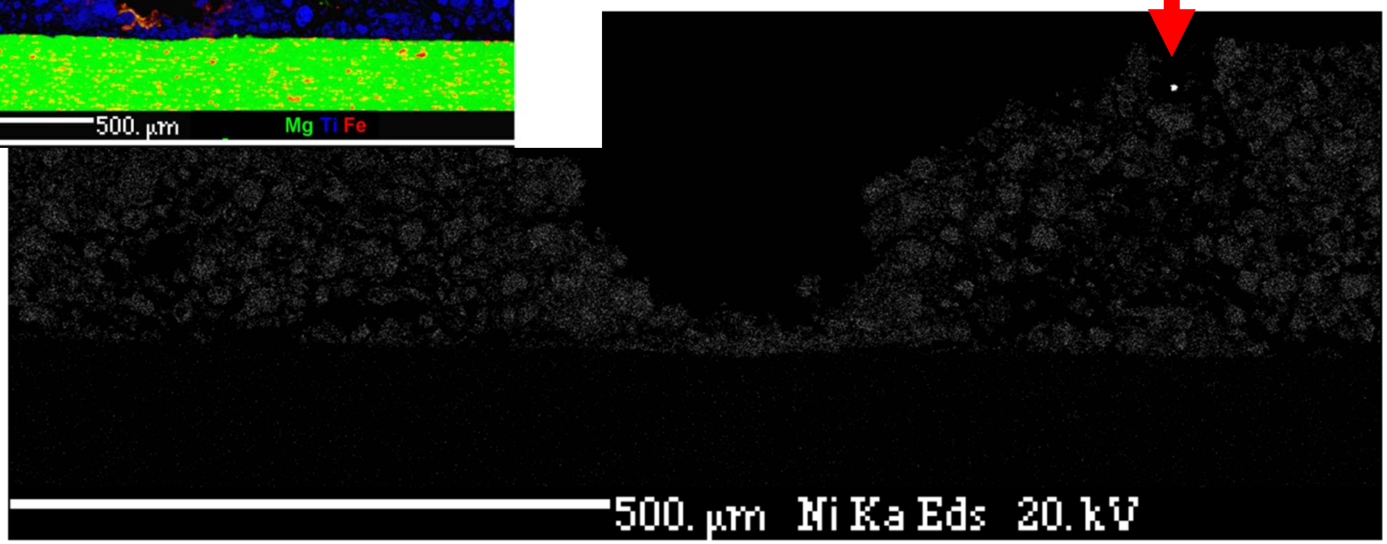


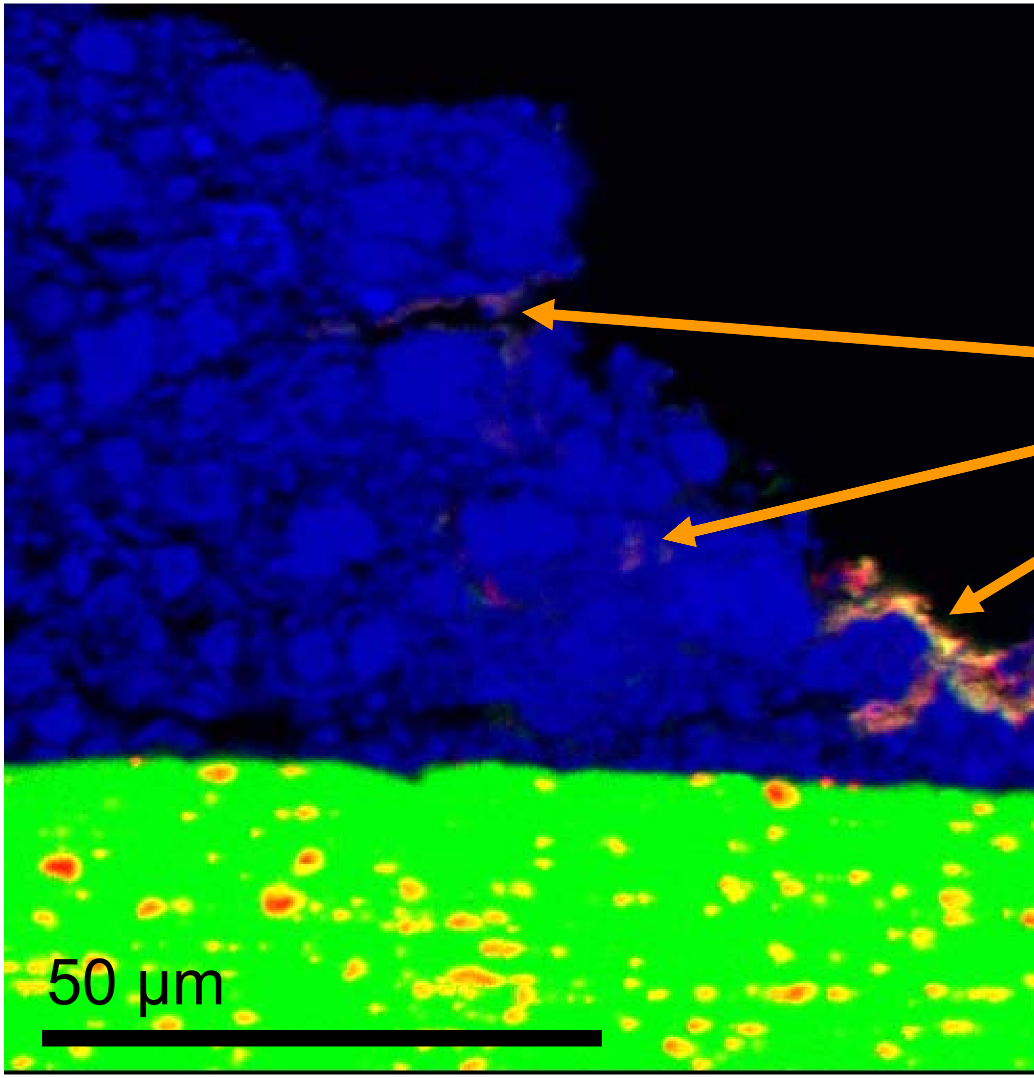
How WFPC2 catches particles

This cross-section taken from NASA White Sands Test Facility calibration impact



Residue lines the crater, and grains are sometimes also caught on the paint surface



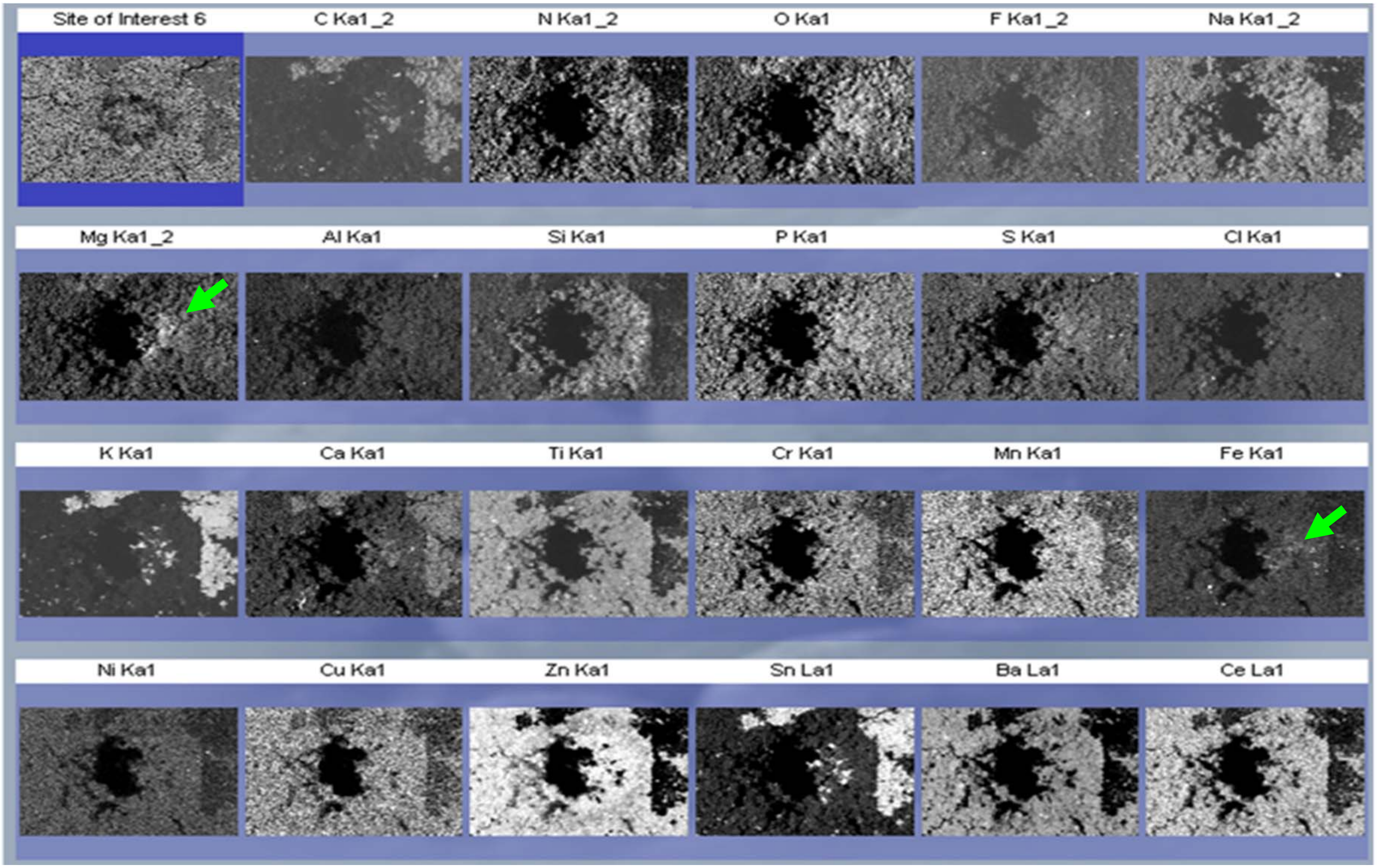


Residue from the impacted particle

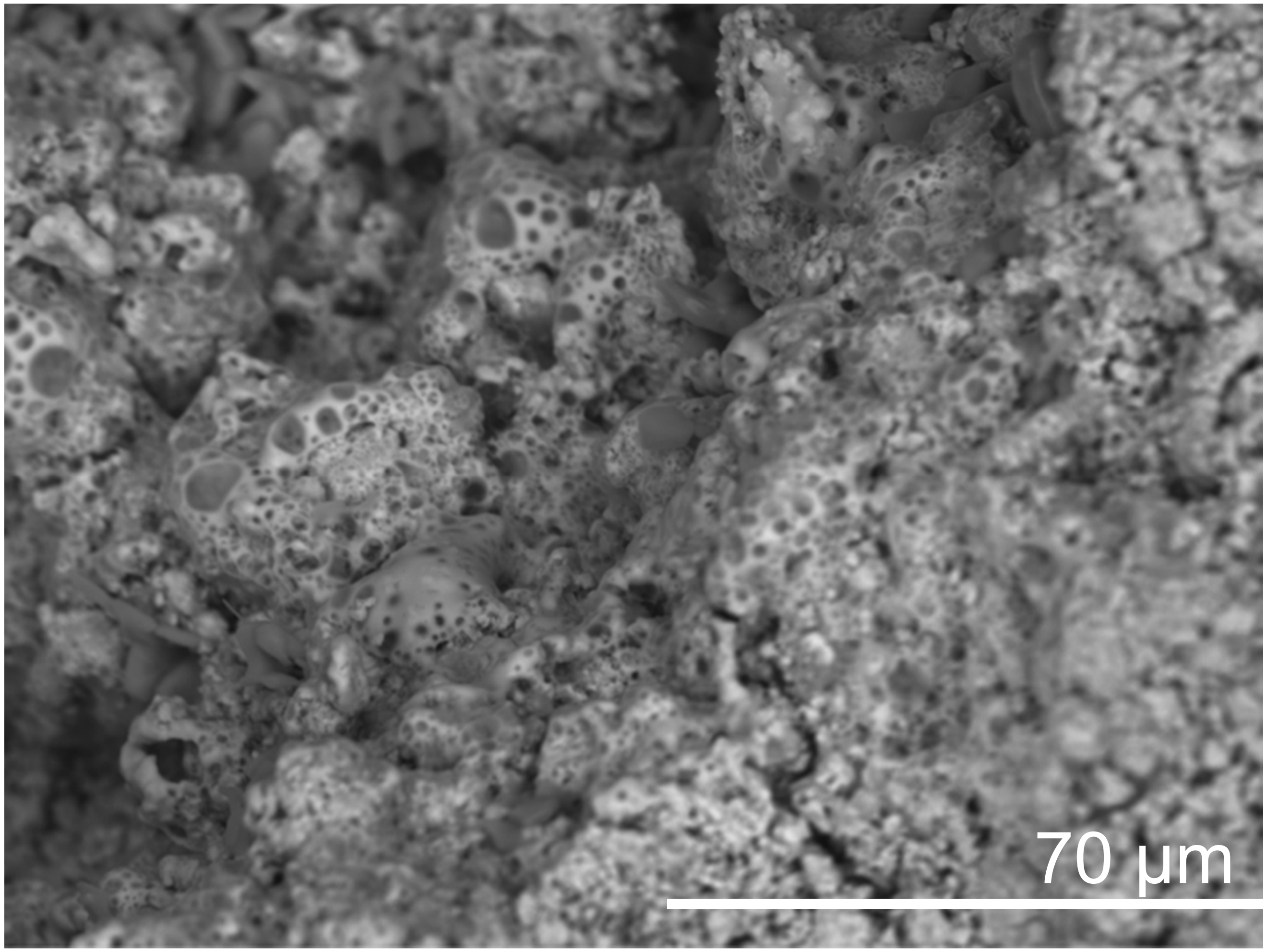
Mg

Ti

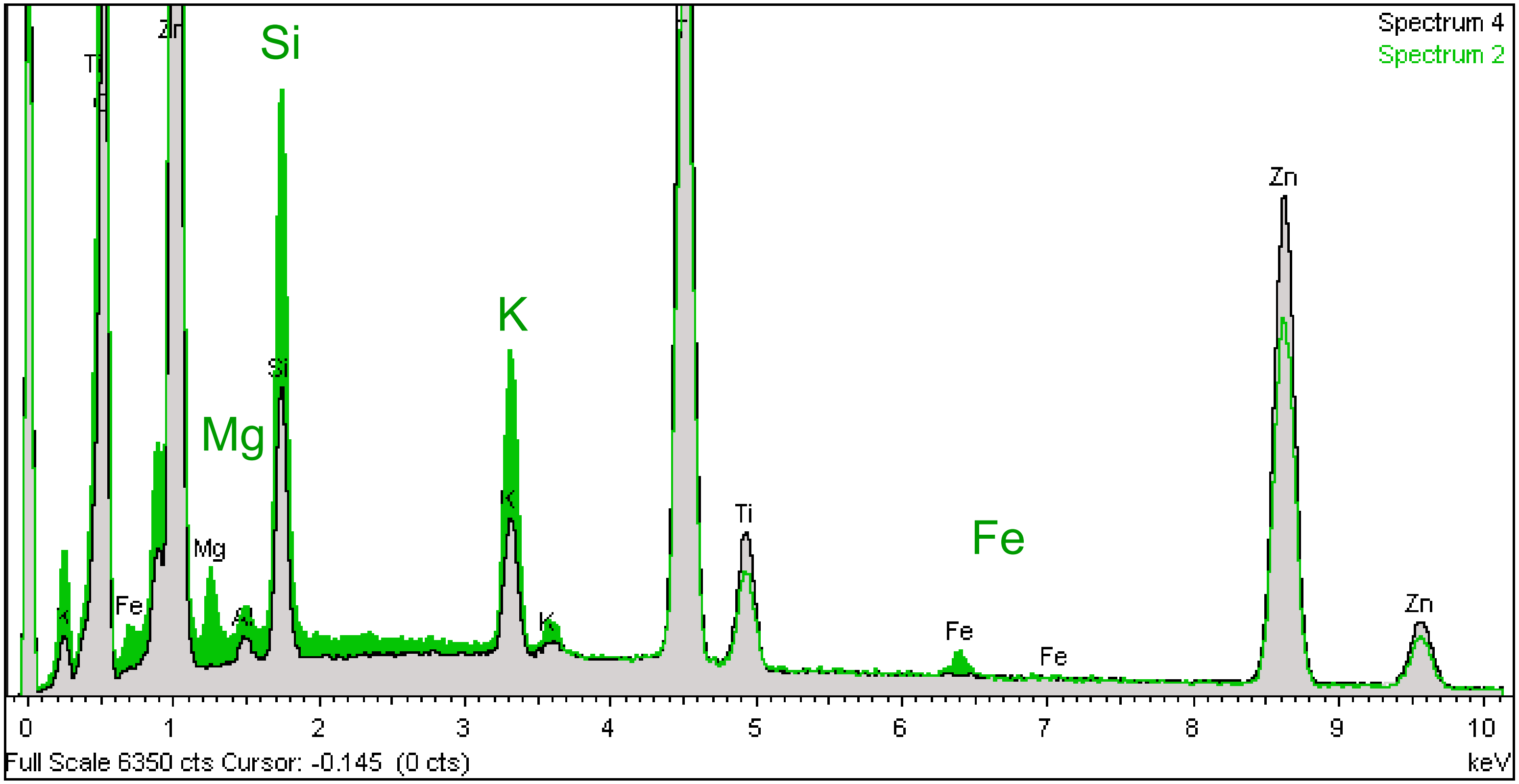
Fe



Automated SEM-EDX maps *sometimes* reveal element enrichments



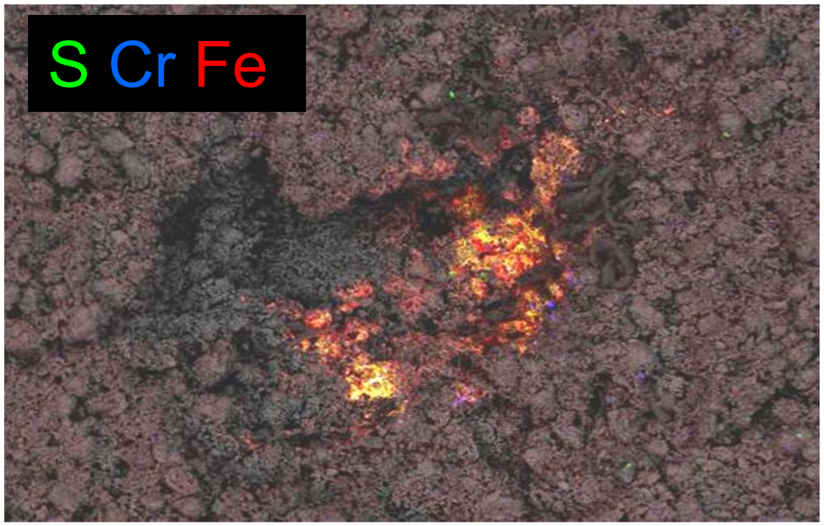
Vesicular (bubbly) melted paint *usually* contains impactor residue



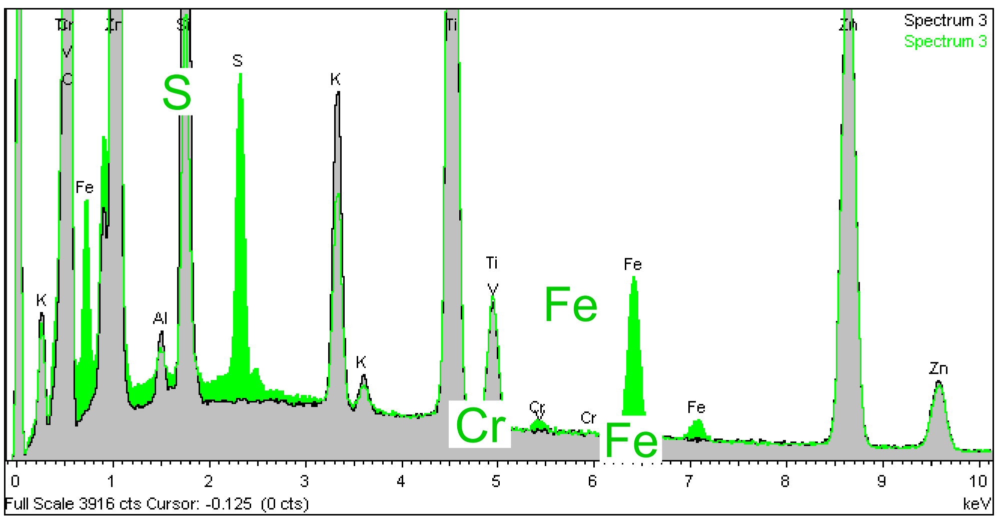
Enriched Mg and Fe

– signature of a micrometeoroid?

Required long EDX spectrum acquisition (200 seconds)



As well as Mg and Fe enriched melts, what else did we find?

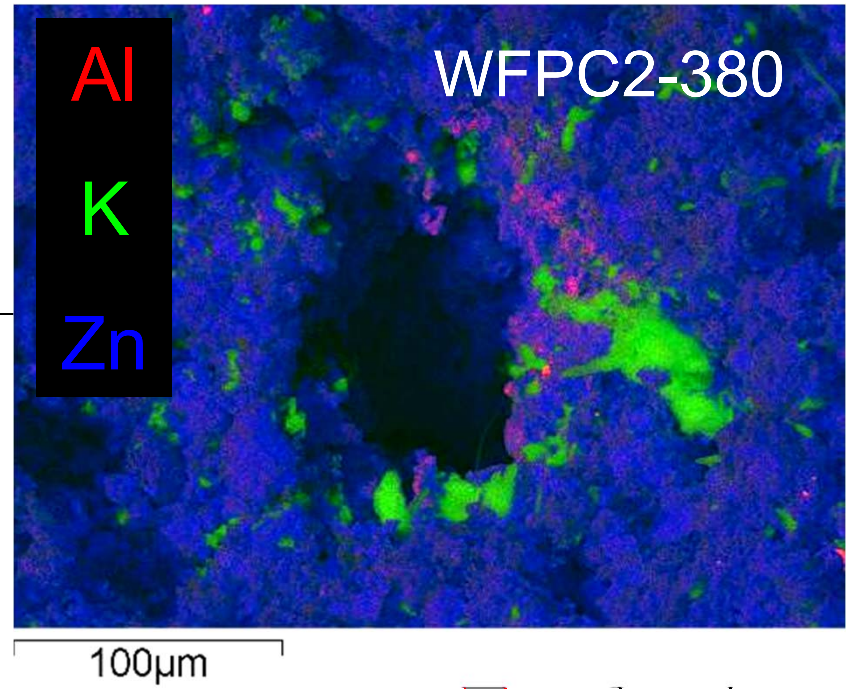


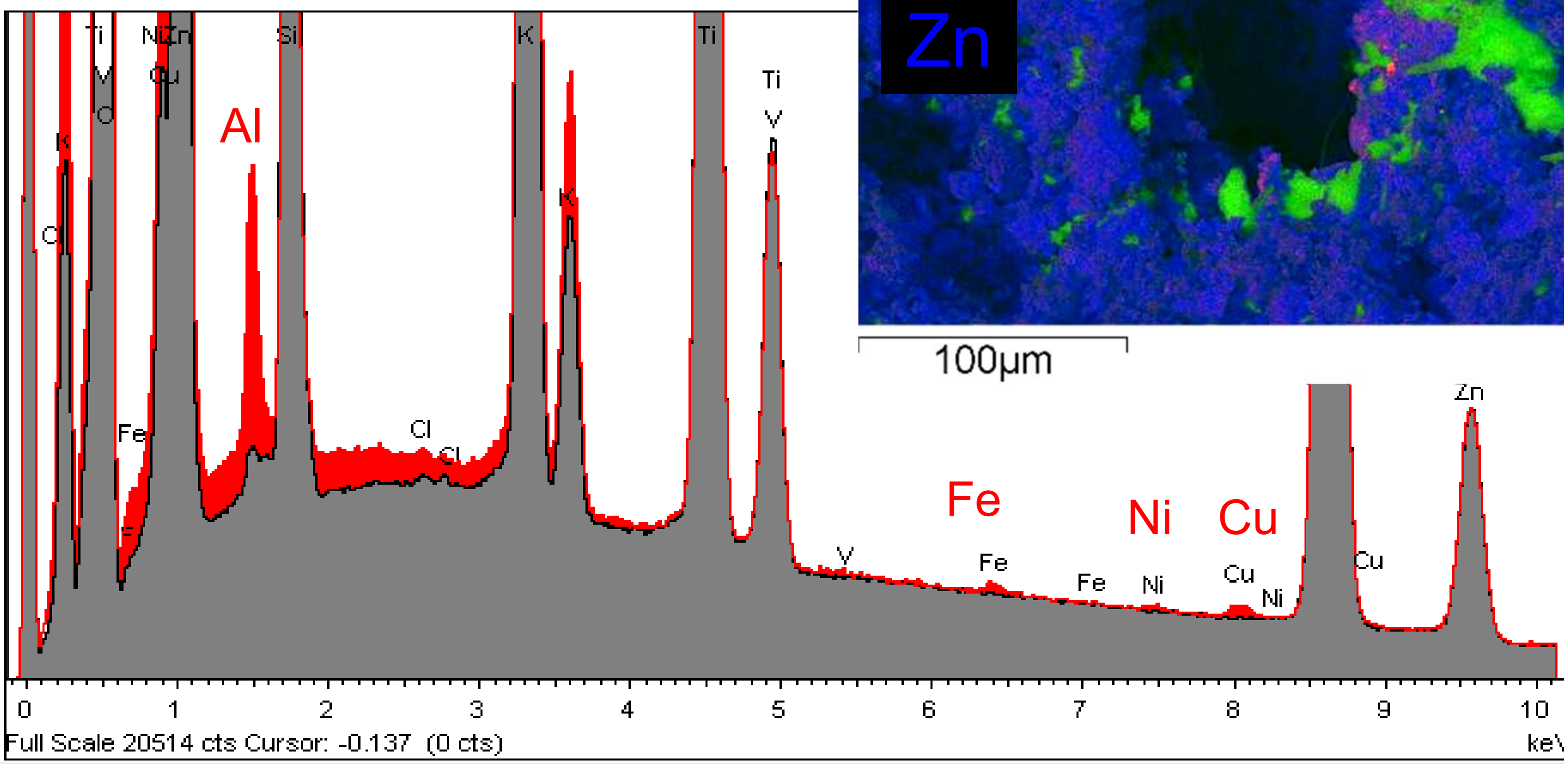
WFPC2-156

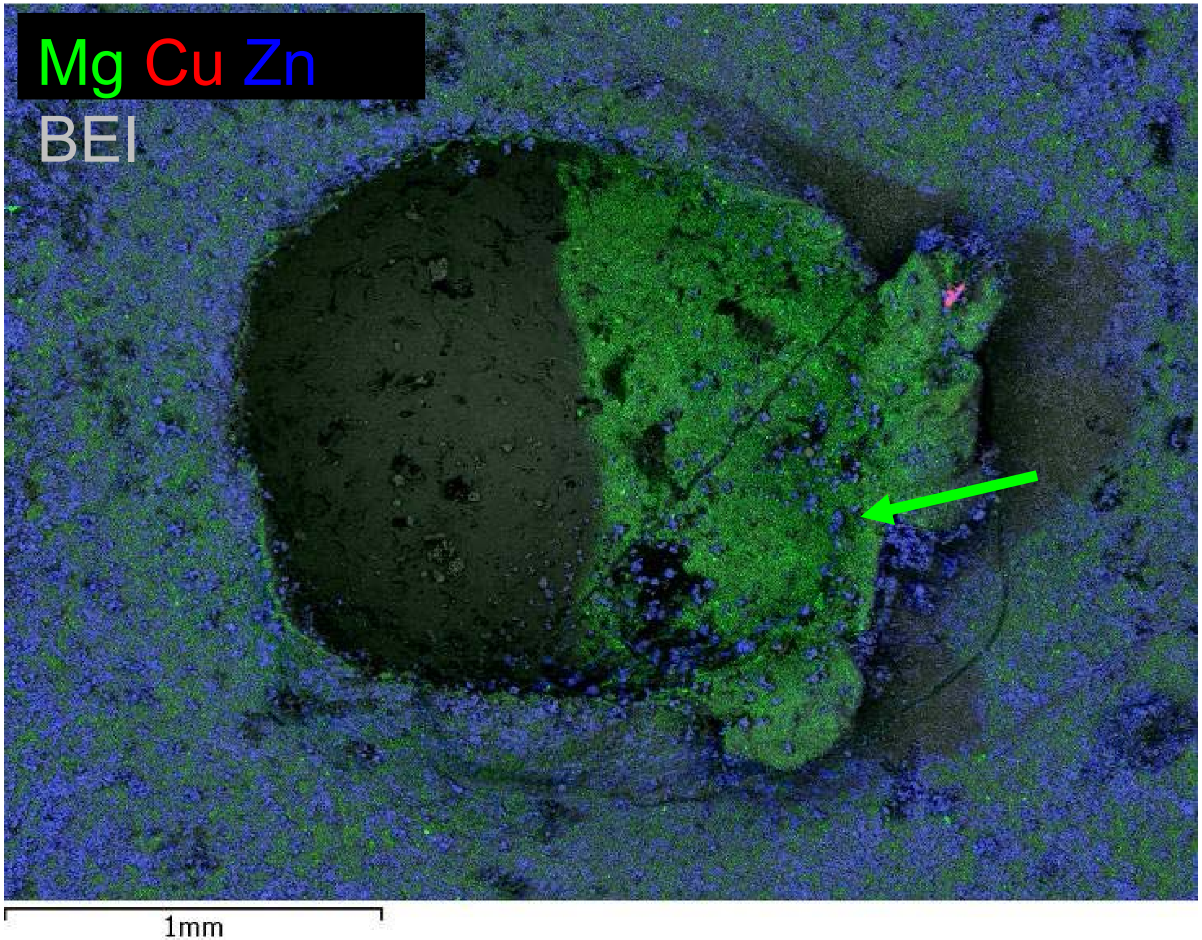
Iron sulfide MM (with Chromium, either in sulfide or as an oxide)

Possible impact by orbital debris

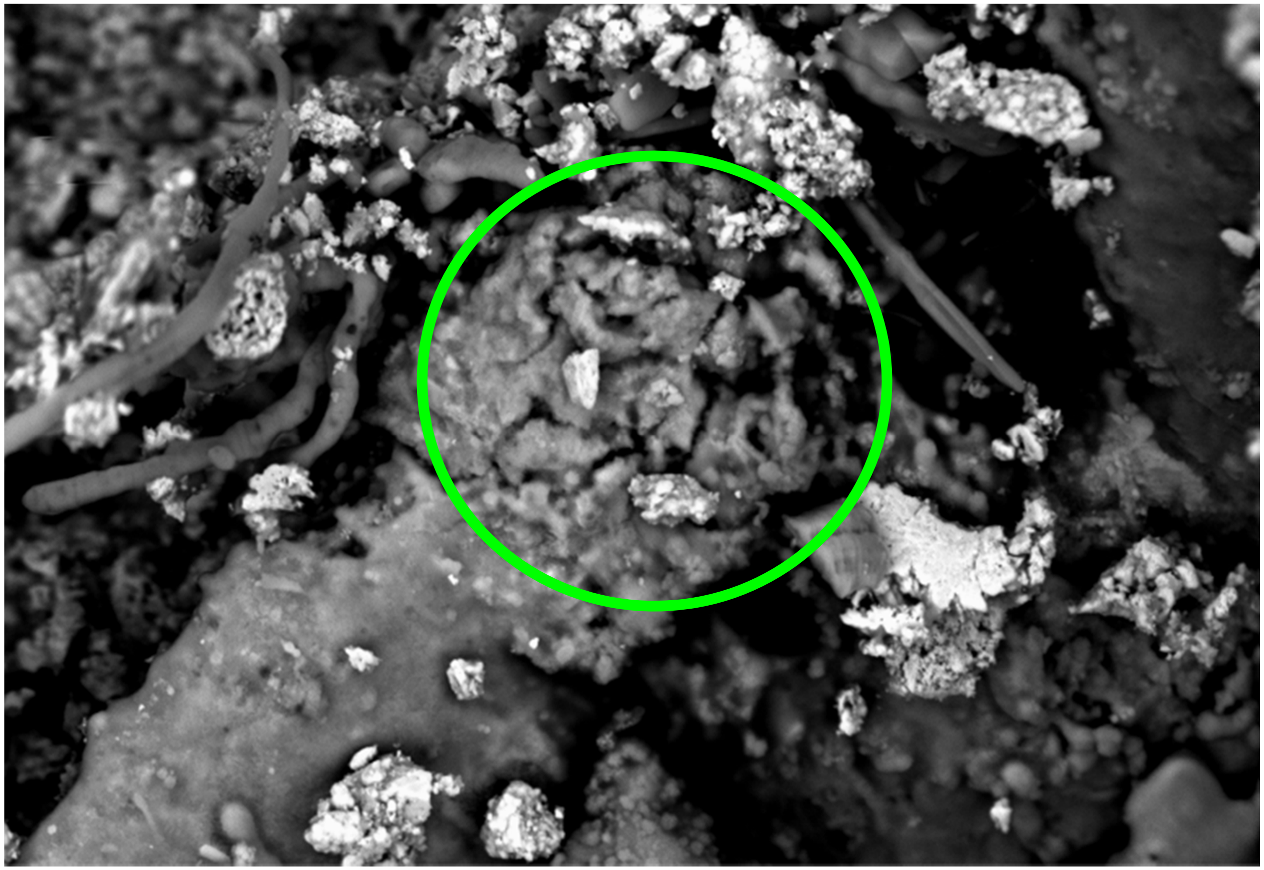
Residue contains trace of Al alloy -with Fe, Cu and Zn





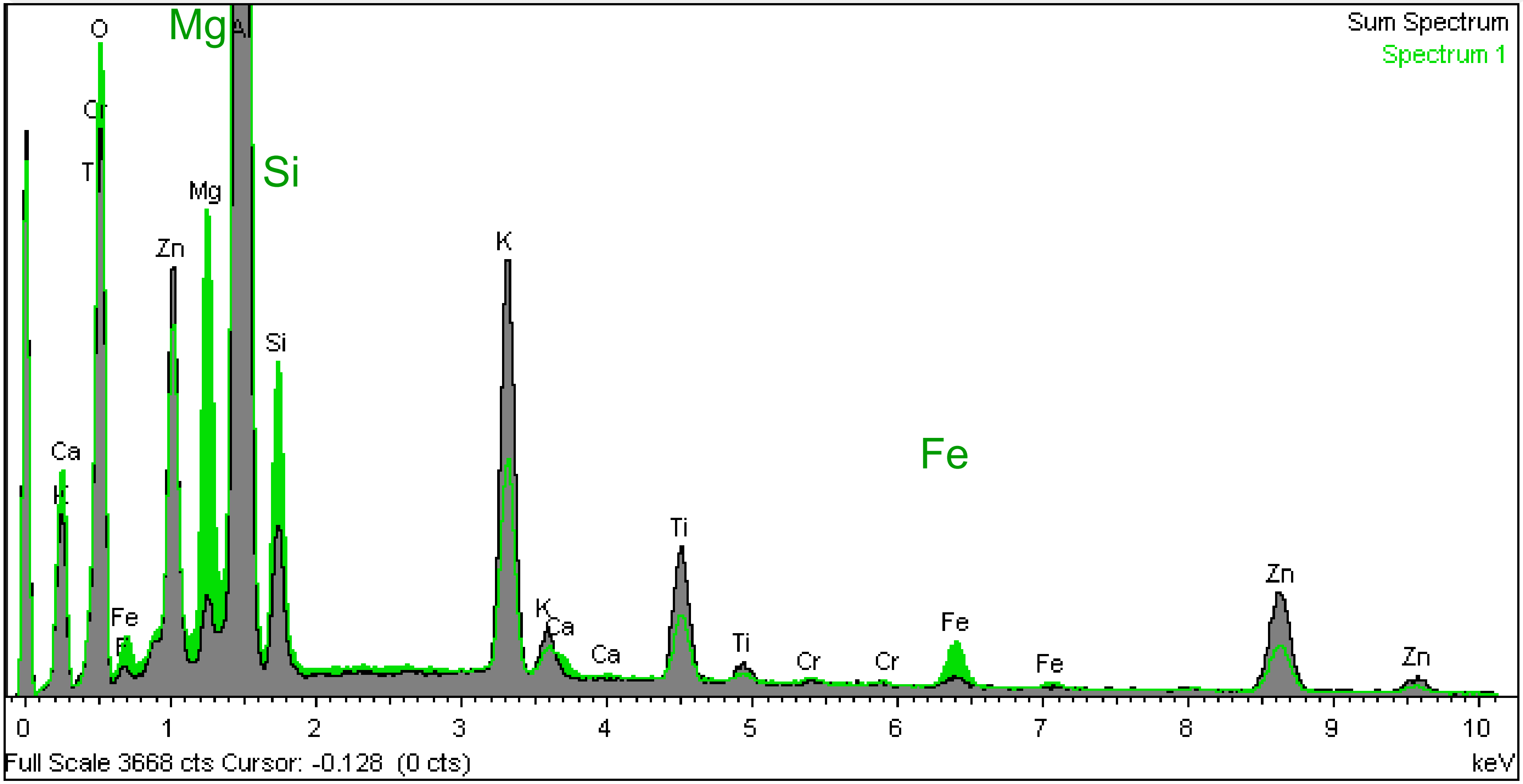


Recognising impactor residue is harder on the alloy
(Al with Mg and Cu; and containing Mg, Si, Cr, Mn and Fe in inclusions).



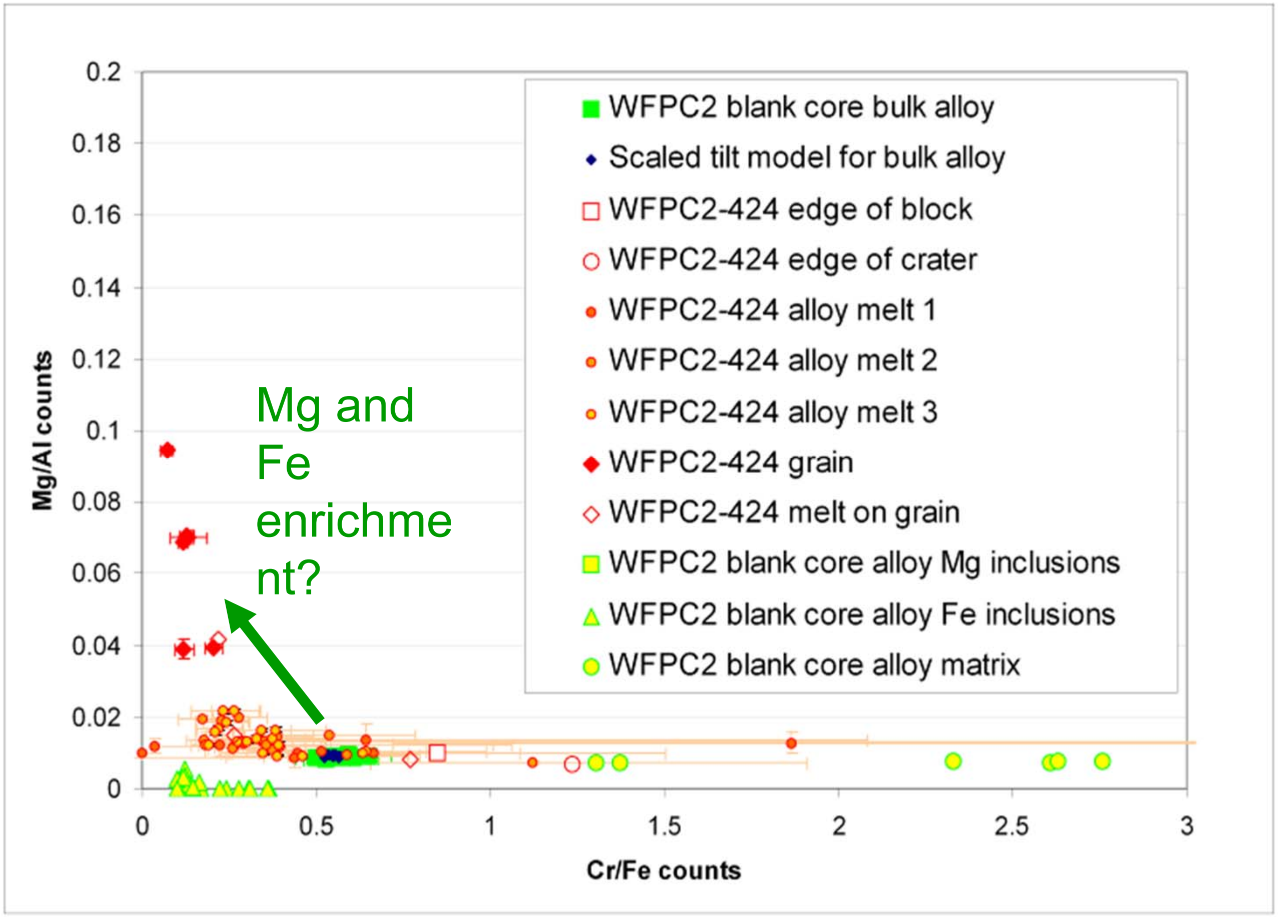
In a few cases it's not just an enrichment, but a piece of impactor.

~ 50 μm across ≈ 1% of the impacting micrometeoroid?



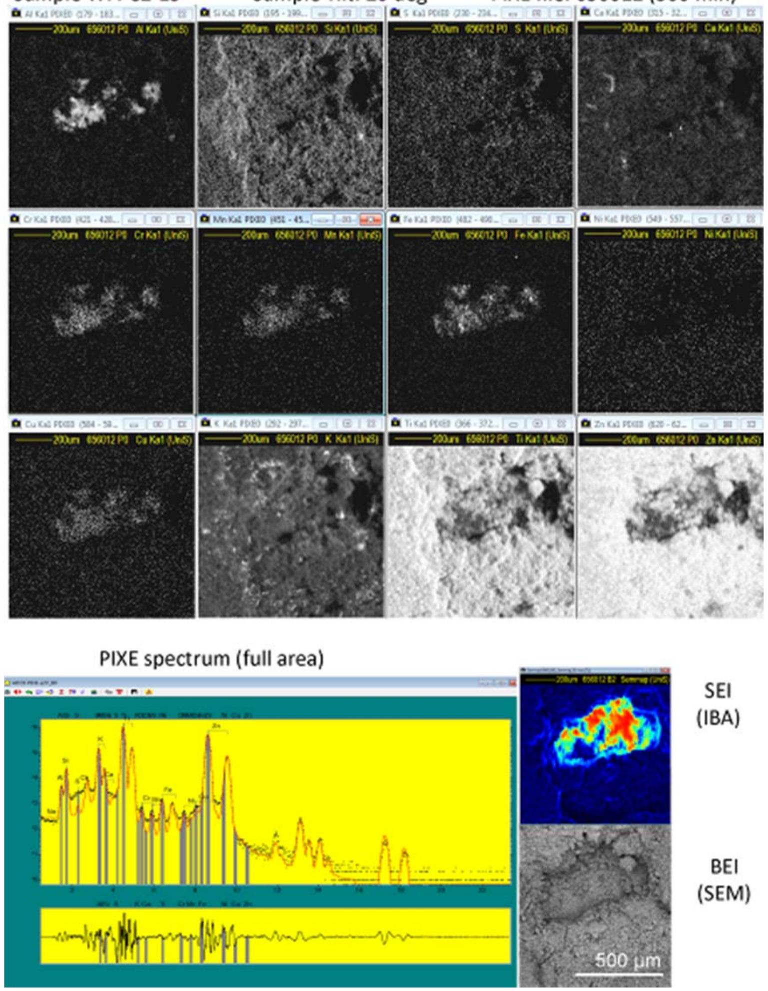
WFPC2-424

O, Mg, Si and Fe enriched - the captured particle could be olivine?



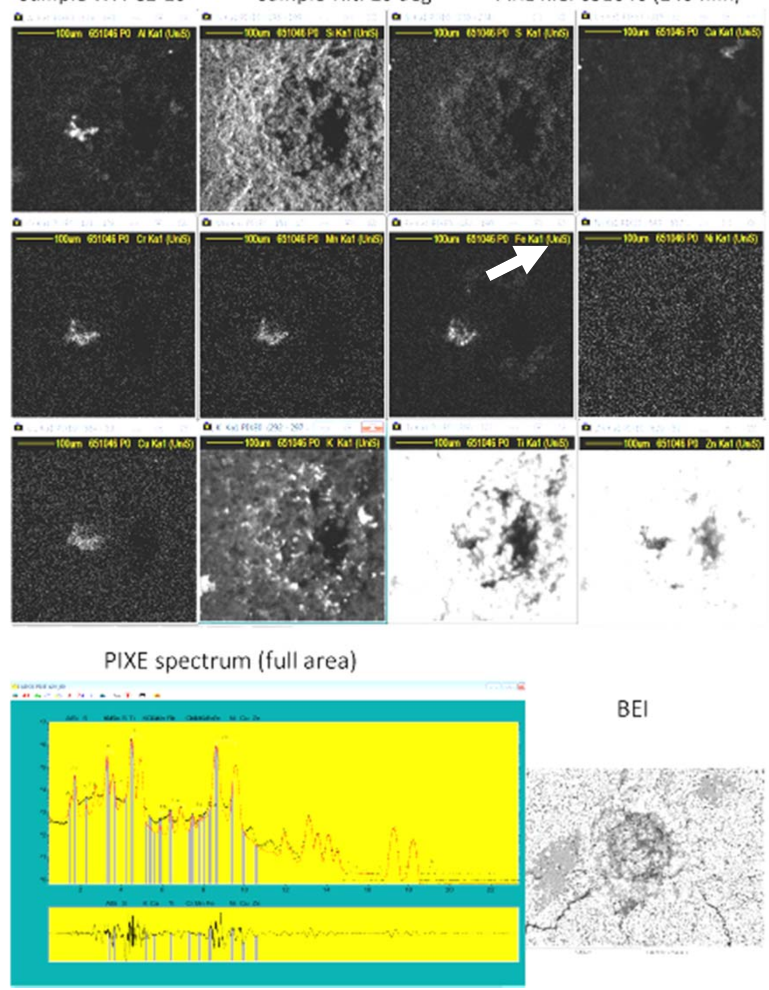
Recognising an extraneous enrichment in alloy melt?
- but sometimes just too difficult by SEM-EDX

Sample WFPC2-15 Sample Tilt: 20 deg PIXE file: 656012 (300 min)



All Fe in alloy inclusions

Sample WFPC2-10 Sample Tilt: 20 deg PIXE file: 651046 (240 min)



Some Fe in melt on paint

Current activities

- **Residue analysis nearing completion in UK and at JSC**
- **Analysis of HST attitude over WFPC2 exposure on-going—required to understand relative contributions of MM (weakly directional) and OD (highly directional) environments**
- **NASA White Sands Test Facility calibration impacts being used to develop damage equations for painted surfaces—necessary to infer impactor size distribution for both MM and OD environments**

Summary

- **WFPC2 provides unique measure of the MMOD environment**
- **Results will be incorporated into computer models of OD & MM environments**

Acknowledgements

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